# The Road to PM Understanding

## *"Are we there yet?*

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# *The Road to PM Understanding*

- The Questions in 1997
- The Road We're On
- Progress and the Roads Not Yet Traveled
  - Epidemiology
  - Exposure
  - Mechanisms and Susceptibility
  - Toxicity of PM Components and Sources
- *Are we there yet?*

# *The Questions in 1997*

1. How strong is the short and long term epidemiology?
   - Statistics, other pollutants, harvesting, exposure

2. Exposure
   - Do central monitors represent personal exposure?

3. Mechanisms and Susceptibility
   - Can there be a plausible biological mechanism? Who's affected?

4. Are all particles created equal?
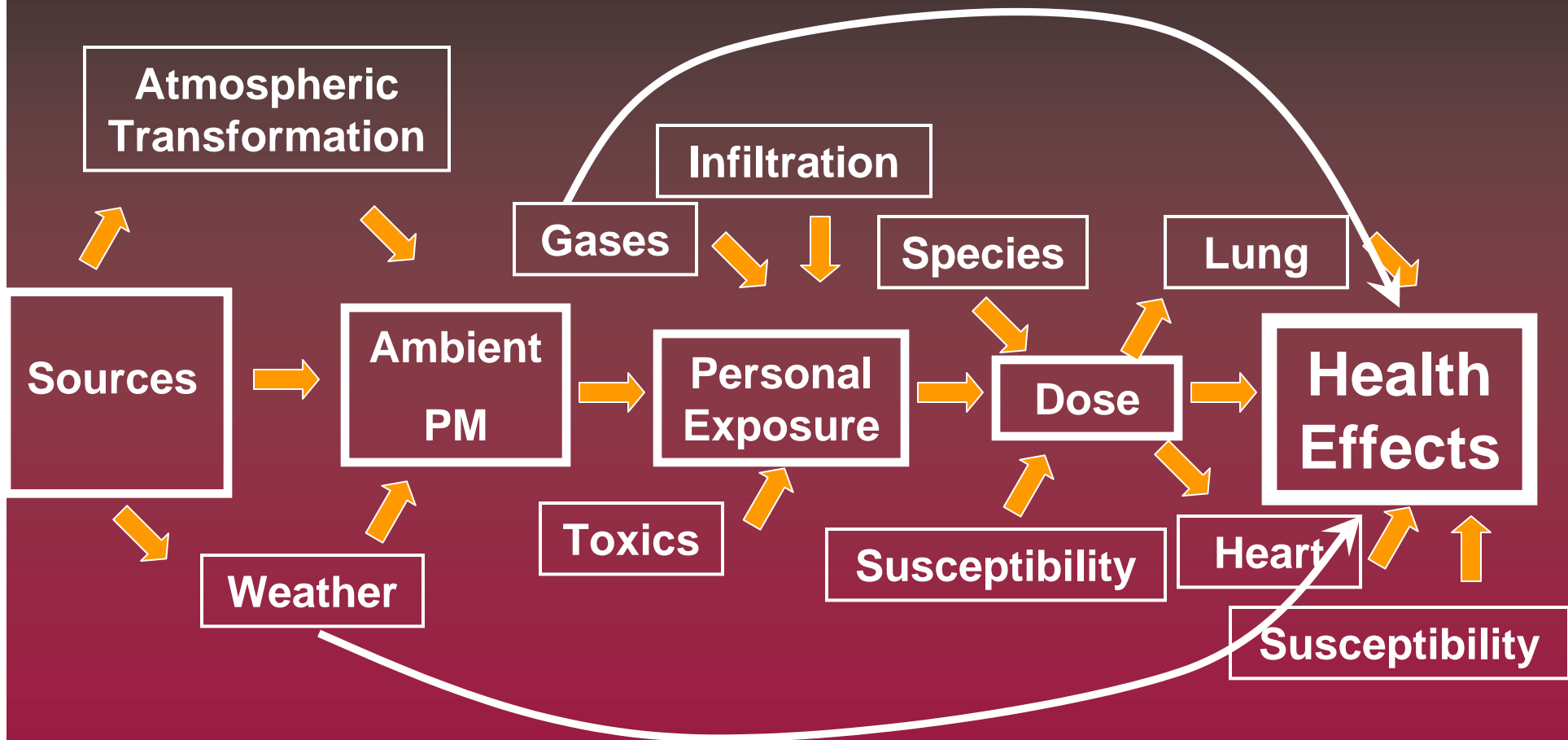   - The toxicity of PM components and sources

# *The Straight and Narrow Road*
## *A General Framework for Integrating PM Research from the NAS report on PM research Priorities 2004*

Sources → Ambient PM → Personal Exposure → Dose → **Health Effects**

# *Measuring Progress*

- Good Science is messy and takes time
  - Multiple paths (and dead ends…)
  - Understanding grows with the number of studies
- The NRC Committee identified a 13-year plan in 1998
  - We are only 6 years into that
- We are going to be at the PM NAAQS for 10 - 20 years
  - SIPs, NAAQS reviews, Accountability

# 1. Epidemiology
## The Questions in 1997

- Could the time series studies be right?
  - Statistical methods
  - Other pollutants, PM sizes
  - Exposure
  - "Harvesting"
- Could the few longer term studies withstand close scrutiny?
- NRC Topics 7, 10

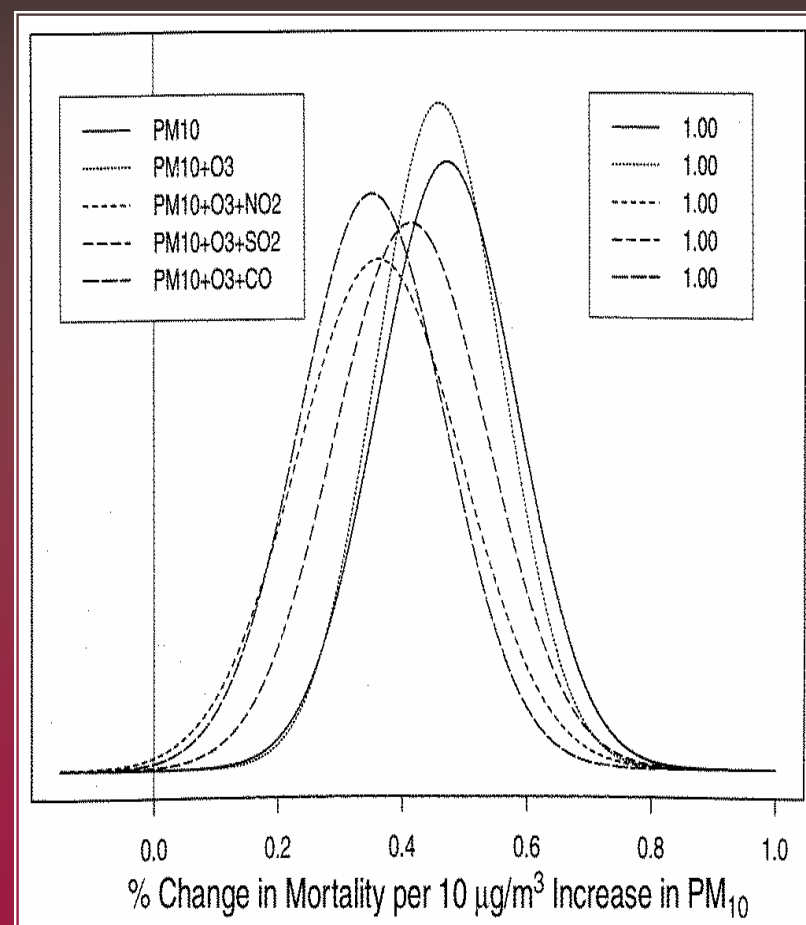# *Epidemiology:*
# *Progress on Short Term Effects*

- Systematic Multi-city studies
  - National Morbidity, Mortality and Air Pollution (NMMAPS) funded by HEI
  - APHEA in Europe funded by EU
- More studies with PM2.5, and the gaseous pollutants
- First efforts on components, sources

# NMMAPS
## The Original Results (HEI 2000)

- Relatively Consistent Increase in Mortality:
  - 0.4% per 10 $\mu$ /m$^3$ of PM $_{10}$
- Smaller results than previous U.S. analyses
- Apparently not sensitive to inclusion of other pollutants
- Enhanced confidence in results
- Some continuing questions
  - Especially different results in different regions

# *NMMAPS*

## Concentration - Response for the 20 Largest US Cities
### *(Daniels et al HEI 2004)*
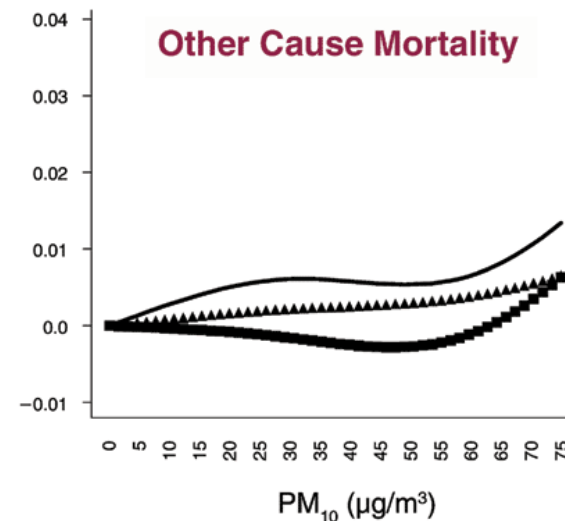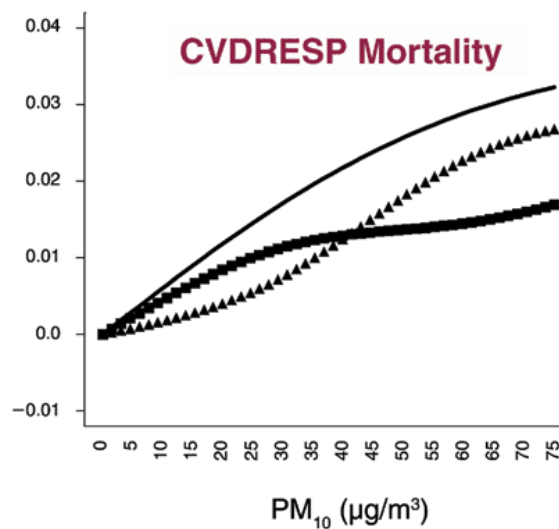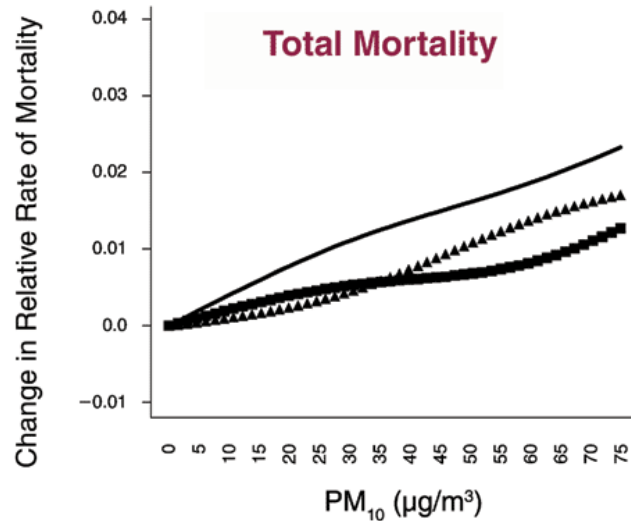
# *Epidemiology:*
## *Progress on Long-term Effects*

- Reanalysis by HEI of two major long-term studies
  - Harvard 6 Cities and American Cancer Society (ACS)
- Follow-up of the ACS cohort (JAMA 2002)
- A few additional studies reported
  - Southern California Children's Study
  - Veteran's Study
  - Netherlands Cohort Pilot Study

# *Reanalysis Results*
## Sensitivity Analyses with Additional Variables

- **Overall, the reanalysis**:
  - Assured the quality of the data
  - Replicated the original results,
  - Tested those results against alternative explanations *without substantively altering the original findings of an association between indicators of particles and mortality*

- *However*, **also identified:**
  - Relationship with education
  - Effects of SO2
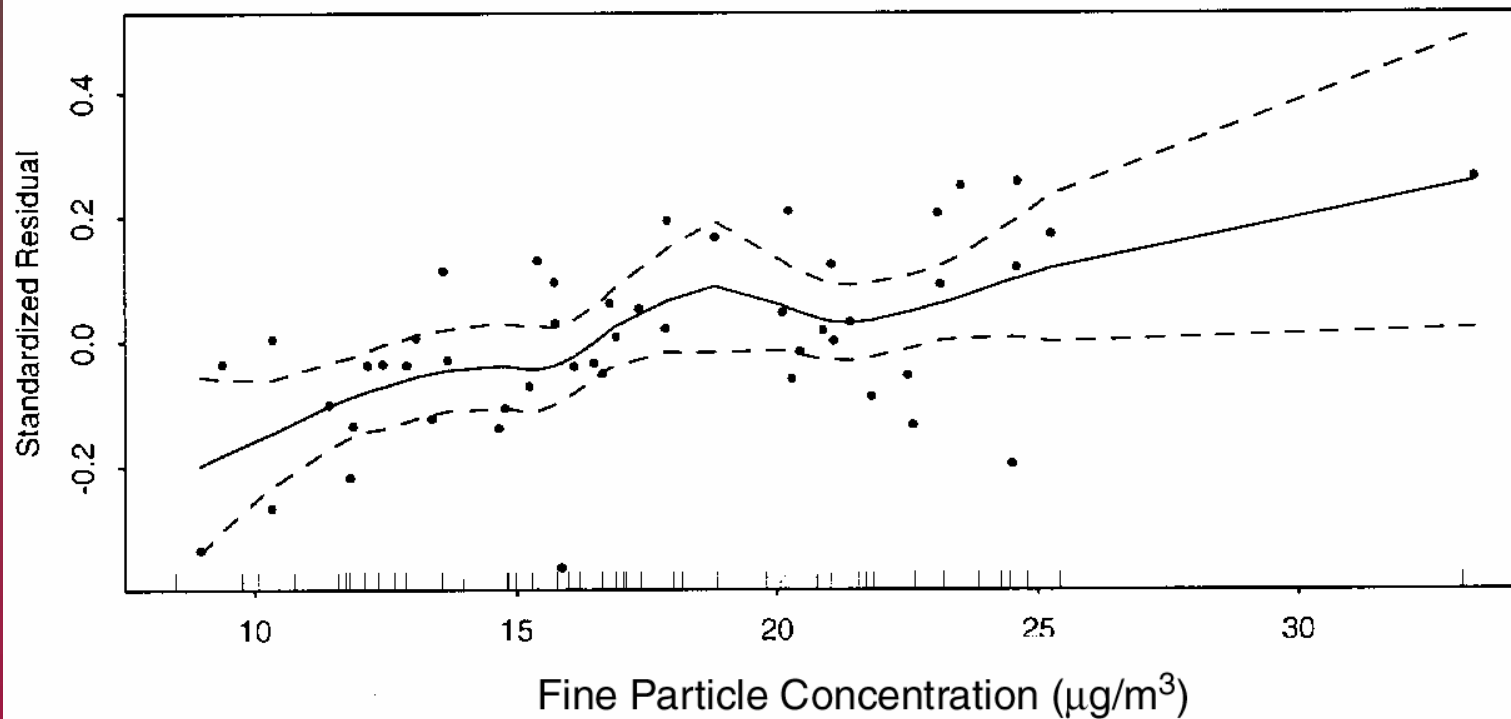
**Results from ACS Study Reanalysis**

| *Analysis* | *PM2.5* | *Sulfates* |
|---|---|---|
| Original | 1.**17**(1.08,1.27) | 1.**15**(1.08,1.22) |
| Full | 1.**18**(1.09,1.26) | 1.**15**(1.09,1.21) |
| Extended | 1.**18**(1.09,1.26) | 1.**15**(1.09,1.21) |

HEI

# *Reanalysis Results*
## *ACS Cardiopulmonary Mortality PM$_{2.5}$*



Cardiopulmonary Disease Mortality (Excluding Boise City, Idaho)

# *Epidemiology: Continuing Challenges*

- Need for continuous improvement in time series models, how to deal with weather
- We need more long-term studies
  - Still only a handful
- The gases have not gone away
  - Do not seem to eliminate PM effect
  - But several also show associations (SO2, NO2)
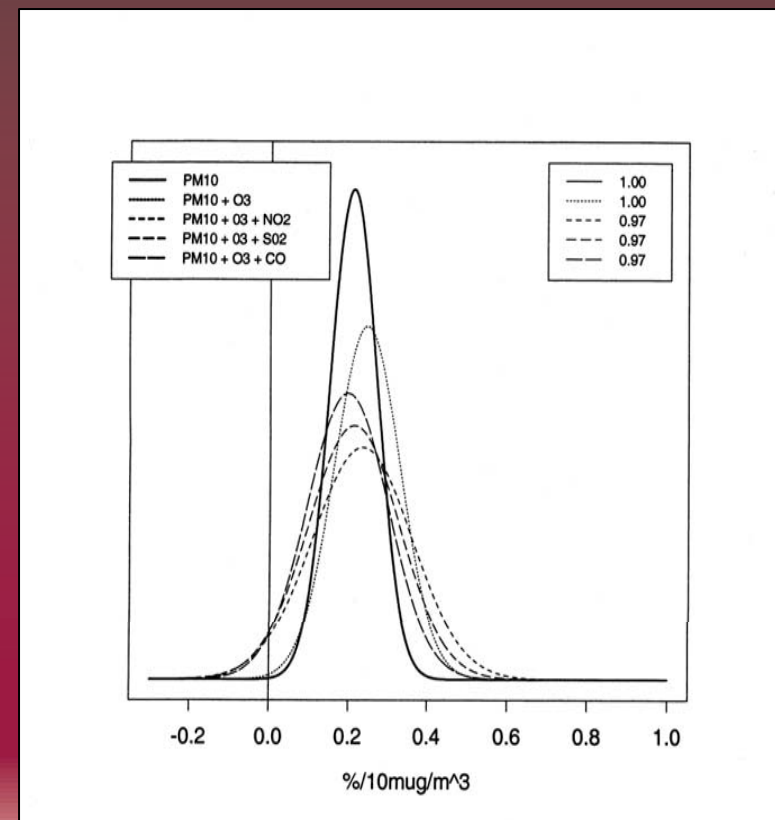  - Does this mean independent effects? A surrogate for something else? Co-effects?

# *The Time Series Models Challenge (GAM)*
# *NMMAPS: Revised Results*

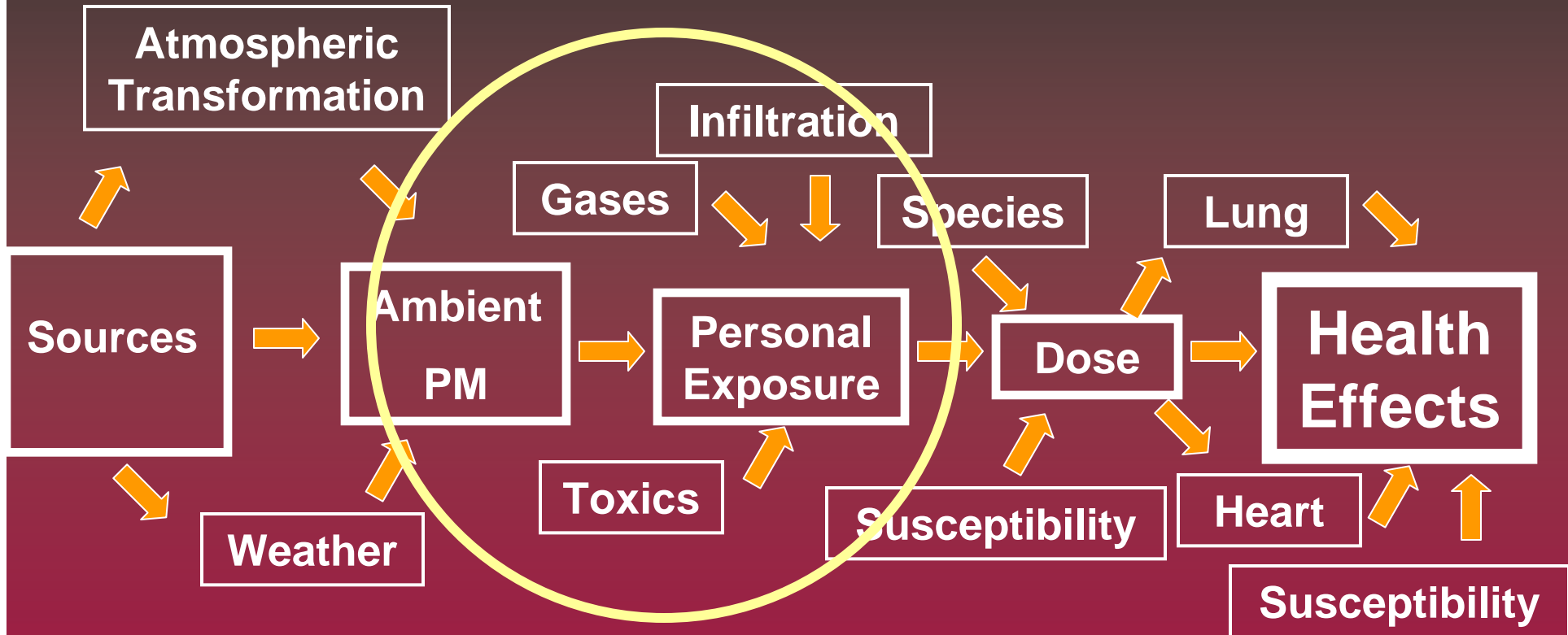## Original Results
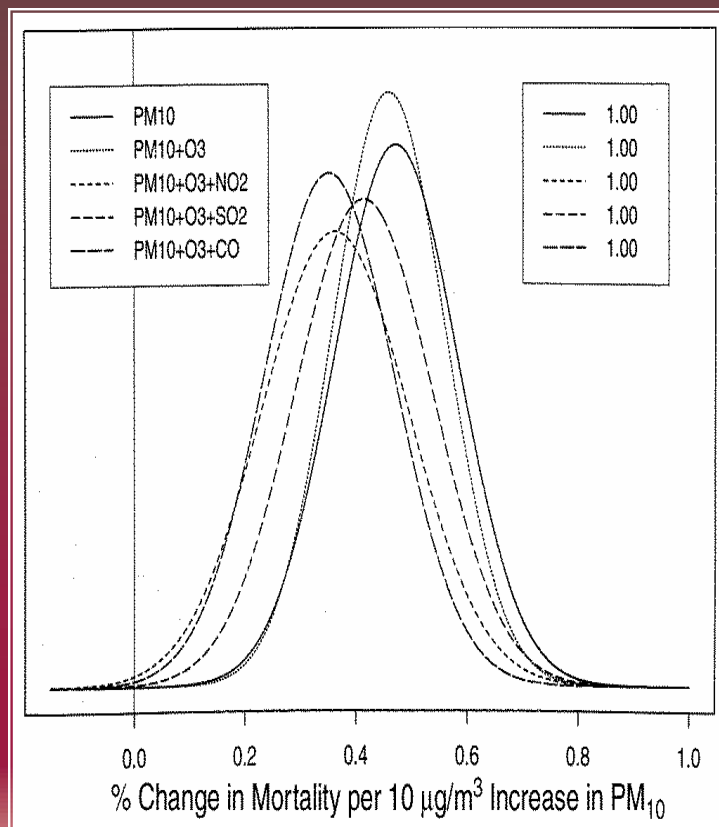
## Revised Results

# *Revised Analysis*

- Over 30 studies identified by CASAC, EPA for reanalysis
- Mean estimates of effects in revised analyses generally smaller
  - 5% to 35% reduction
- Effect for PM10 still does not appear to be affected by co-pollutants
- Reanalyses renewed questions about the role of other factors (especially weather)
- *HEI Review Panel Bottom Line:*
  - Studies continue to find associations with PM
    - some benefits estimates will be smaller
    - Need for continuous improvement



SPECIAL REPORT

**Revised Analyses of Time-Series Studies of Air Pollution and Health**

Revised Analyses of the National Morbidity, Mortality, and Air Pollution Study, Part II *

Revised Analyses of Selected Time-Series Studies *

* All references to Minneapolis give values for Minneapolis and St. Paul.

HEALTH EFFECTS INSTITUTE
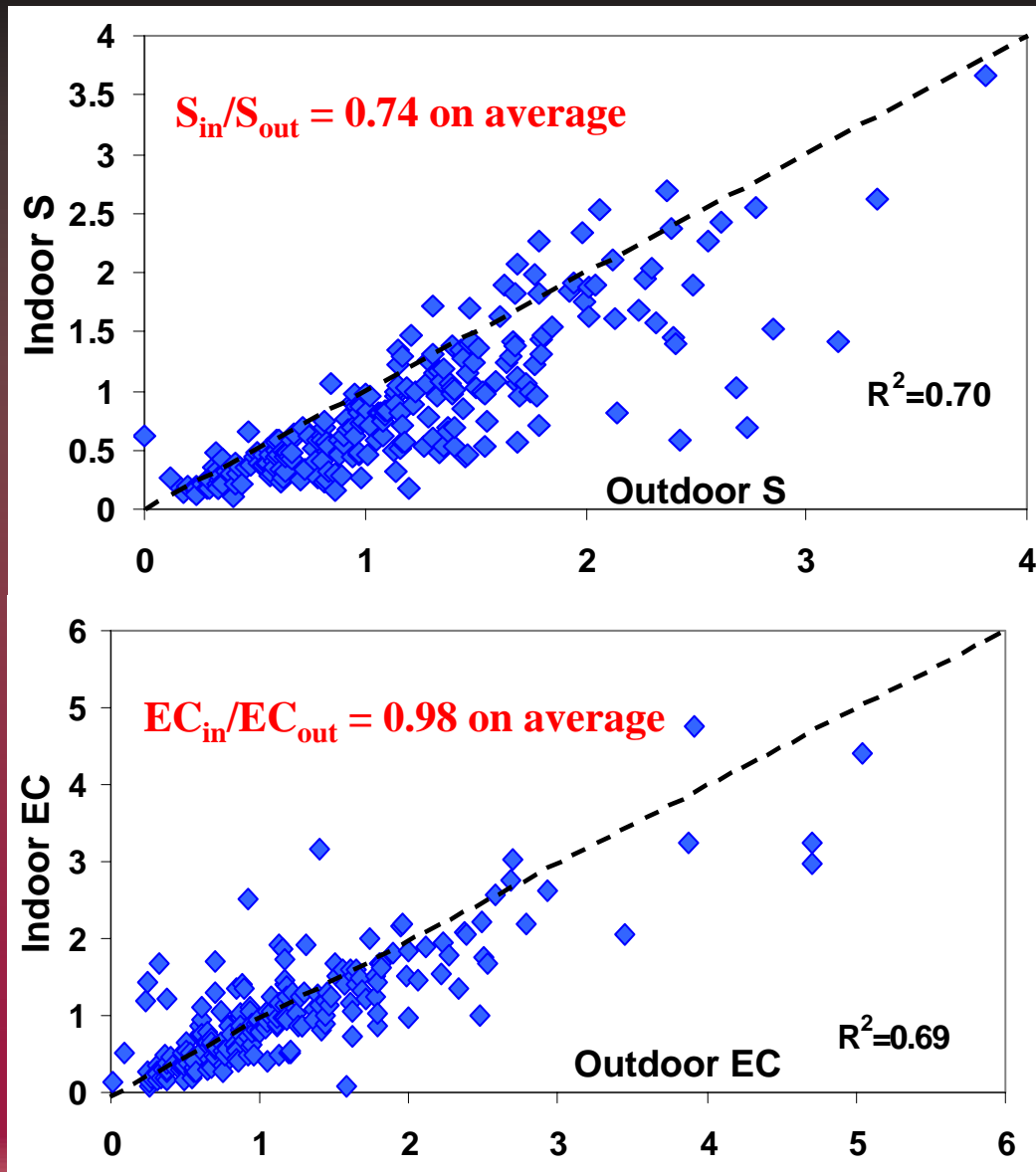
May 2003

# 2. *Exposure*

# *Exposure Progress*

- Can central monitors reflect actual personal exposure? (NRC Topics 1, 2)
  - Few studies available in 1997
- A number of new studies now completed
  - EPA, HEI, API, EPRI
  - Outdoor, indoor and personal monitors
  - Elderly, children, asthmatics
- Outdoor PM contributes significantly to PM exposure
  - Other sources not correlated day-to-day with PM

# Tracers of Outdoor Contribution to Indoor PM(RIOPA)



$S_{in}/S_{out} = 0.74$ on average

$R^2 = 0.70$

Indoor S / Outdoor S

$EC_{in}/EC_{out} = 0.98$ on average

$R^2 = 0.69$

Indoor EC / Outdoor EC

✓ **S used as a tracer to determine the contribution of outdoor PM to indoor PM (Outdoor contribution to indoor PM = $S_{in}/S_{out}*PM_{out}$).**

✓ **S tracer for regional PM**

✓ **In RIOPA, indoor and outdoor EC are highly correlated.**
✓ **Few homes appear to have indoor sources of EC.**
✓ **EC tracer of local combustion.**

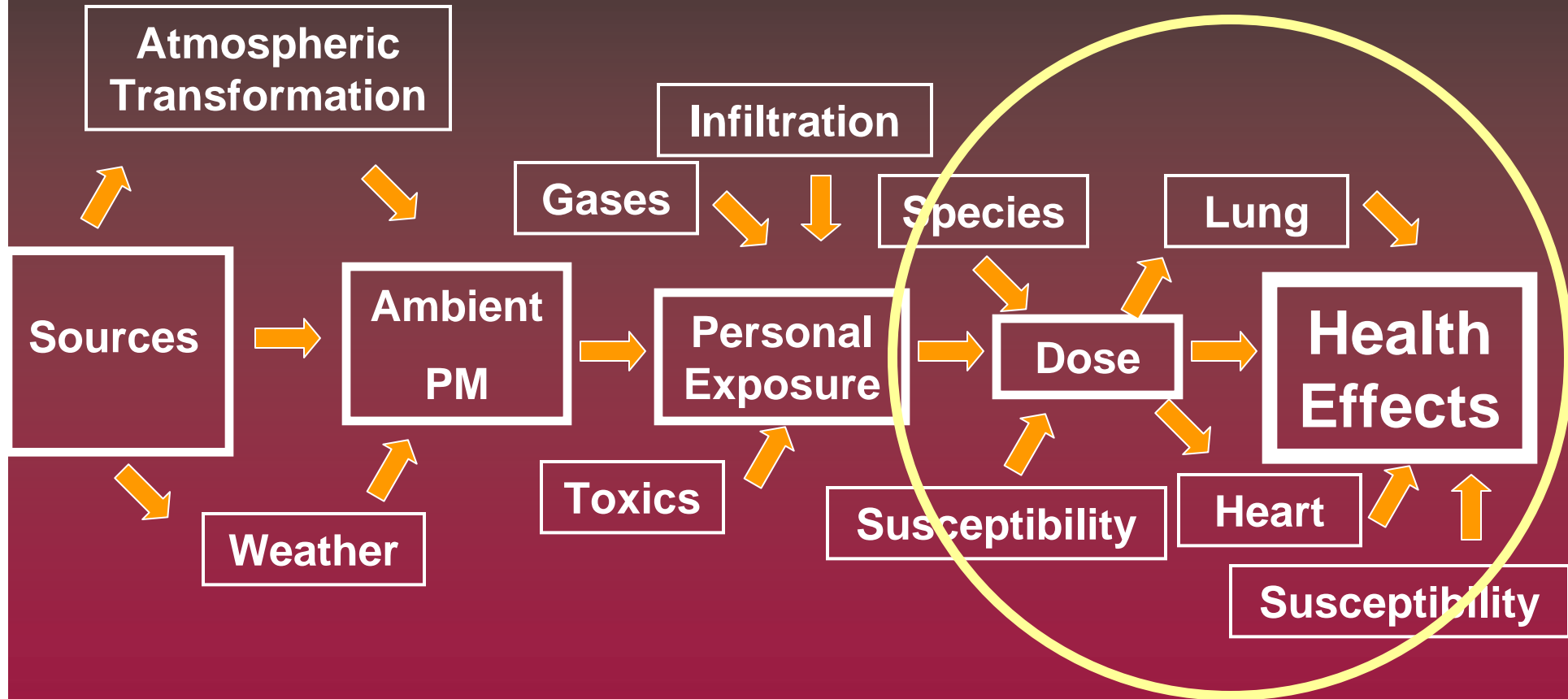Courtesy of B Turpin (RIOPA study), presented at AAAR 2003 PM Colloquium

# *Exposure:*
## *Continuing challenges*

- Need to expand:
  - the number of subjects
  - the types of potentially susceptible individuals
- Better measurement of components and sources of personal exposure
  - NRC Topic 2
- New measurement techniques
  - to enhance ability to detect exposures
  - at lower cost with more precision

# 3. Mechanisms and Susceptibility

**Atmospheric Transformation**

**Infiltration**

**Gases**

**Species**

**Lung**

**Sources**

**Ambient PM**

**Personal Exposure**

**Dose**

**Health Effects**

**Weather**

**Toxics**

**Susceptibility**

**Heart**

**Susceptibility**

# *Mechanisms/Susceptibility Progress*

- 1997: Few studies suggesting plausible mechanisms
  - NRC Topics 6, 8, and 9
- Today:
  - Many potential pathways
  - Some toxicology or epidemiology for each
- Growing number of potential susceptibles
  - Elderly, children
  - Lung disease
  - Cardiovascular disease
  - Other diseases (e.g. diabetes found by Goldberg (2000), confirmed by Zanobetti (2002))

# *Mechanisms/Susceptibility: Continuing Challenges*

- We are in the early stages
  - Latest draft CD notes this in Chapters 7 and 8
  - Need to look at long term mechanisms
  - Need better dose-response info
- First human controlled exposure studies have shown few or modest effects
  - Need more human data (of necessity initial studies have been in healthy or only mildly ill volunteers)
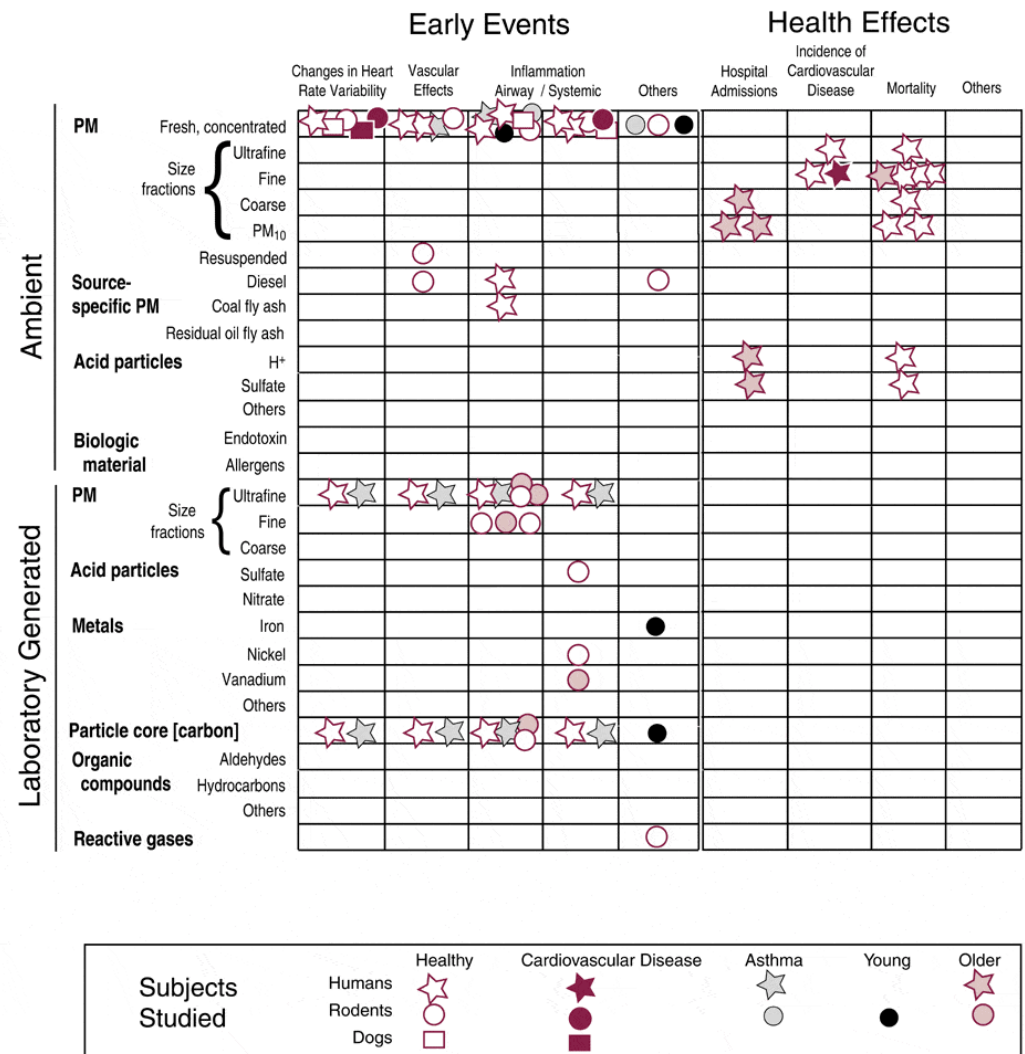- Draw more experts from other health fields into air pollution (e.g. CVD)

# 4. *Toxicity of PM Components and Sources*

- 1997 questions (NRC Topic 5):
  - Is all PM equally toxic?
  - How can we ensure that we control the components and sources with the highest public health effects?
- Progress
  - More epidemiology and toxicology studies on this topic
  - To date:
    - High dose toxicology - most things toxic
    - Many correlated components in epidemiology
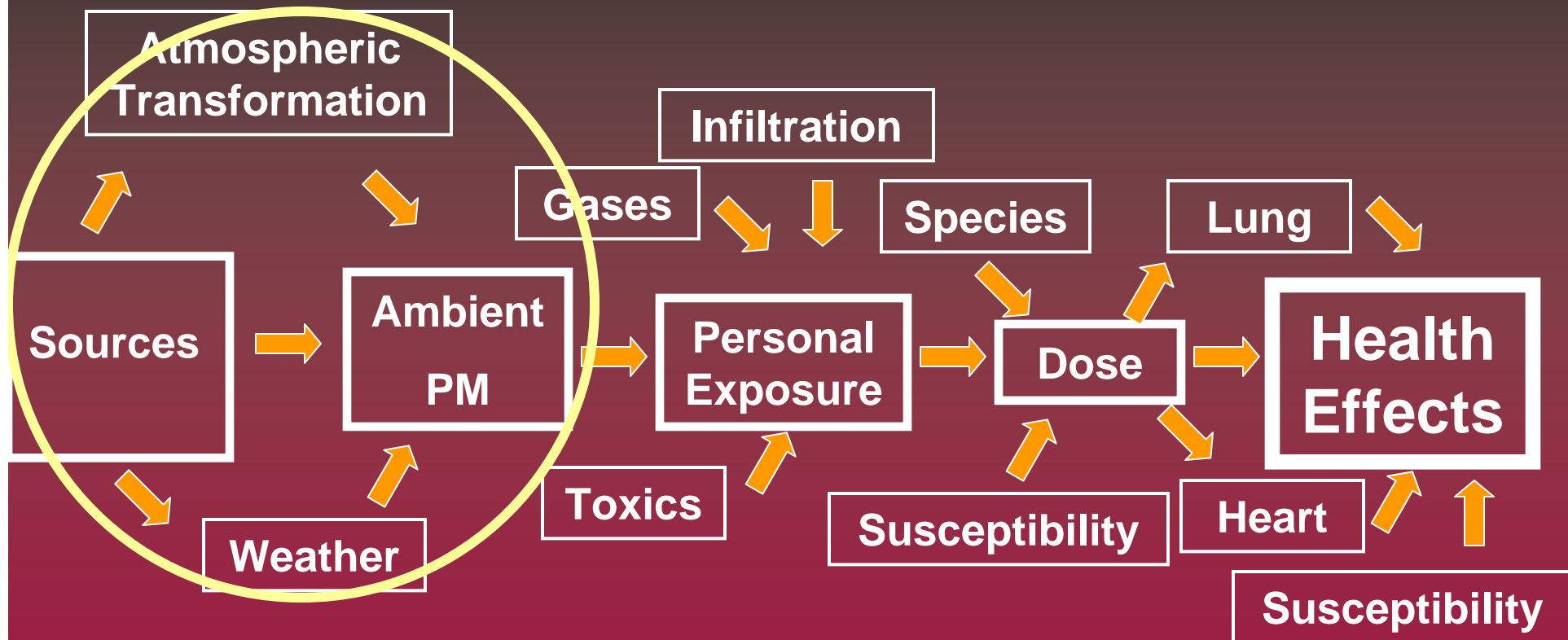    - As yet, few systematic approaches

# *Toxicity of Components and Sources Challenges*

- **Many empty boxes in the "matrix"**

- **Systematic approaches:**
  - Tox: comparable tests of all components; realistic exposures
  - Epi: systematic multi-city approaches
  - Better tools for linking effect, components, gases, and sources
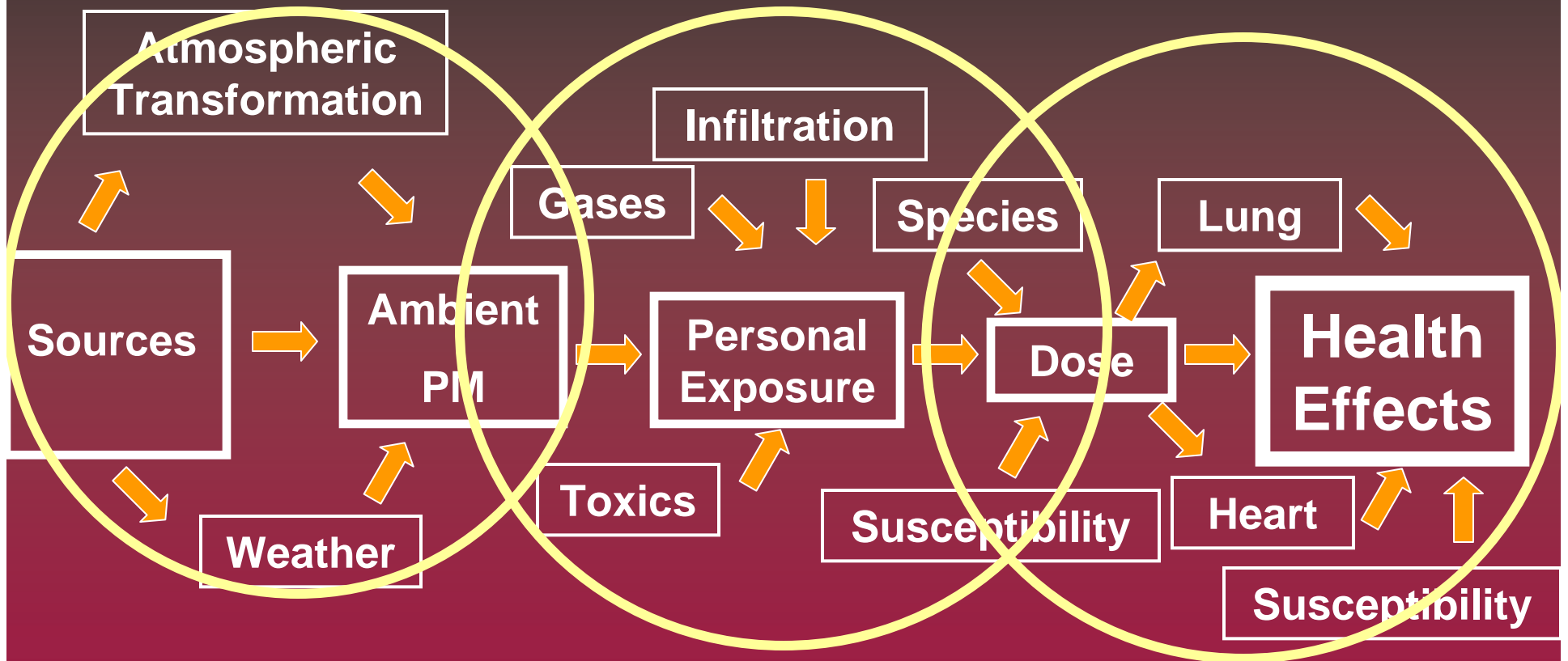
# 5. Tools for Source Apportionment

# *Are we there yet?*

Atmospheric Transformation

Infiltration

Gases

Species

Lung

Sources

Ambient PM

Personal Exposure

Dose

Health Effects

Weather

Toxics

Susceptibility

Heart

Susceptibility

HEI

# *Are we there yet?*

- We've made progress on the road to PM understanding

- We know more about:
    - The epidemiology
    - Exposure
    - A series of possible mechanisms and susceptible populations

# *Are we there yet?*

- To reach our final destination – *cost effective public health strategies for PM over the next 10 years* – we will need:
    - Continuous improvement in epidemiology (models, more long term studies)
    - Improved mechanistic understanding (dose-response, long term)
    - A systematic approach to toxicity of PM components and sources (and the gases!!!)
    - Enhanced tools for source apportionment

*Thank You!*

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